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XX.—*On the Red Crag and its Relation to the Fluvio-marine Crag, and on the Drift of the Eastern Counties.* By S. V. WOOD, Jun.

[With a Map, Plate XVII.]

SOME observations made during a visit to the Red-Crag beds disclosed such peculiar conditions of structure that I was induced to enter upon a careful and minute survey of the whole Red-Crag area. The result of that survey, with the observations that I have been enabled to make upon the Drift-beds of the counties of Essex and Suffolk, form the subject of this paper; and they have led me to the conclusion that in the Red Crag (once regarded as of Miocene age) we have the initiatory stage, in England at least, of that series of events which, chiefly studied under the term *drift*, began by the encroachment upon the land of England of a bay of the Northern Ocean, progressed by the extension of that bay into what now forms the Eastern Counties, and eventually involved a far more extensive area in a submergence beneath the sea that furnished the ice-borne sediment and detritus known as the northern Clay-Drift.

I have thought it more convenient to embody in an appendix a list of the various sections of Red Crag examined by me. They are taken from every part of the Red-Crag area, and comprise, with the exception only of Felixstowe, almost every Red-Crag exposure between the Alde and the Orwell, as well as several south of that river.

It will be perceived, from the diverse shading upon the map (Pl. XVII.) accompanying this paper*, that the Red Crag is divided

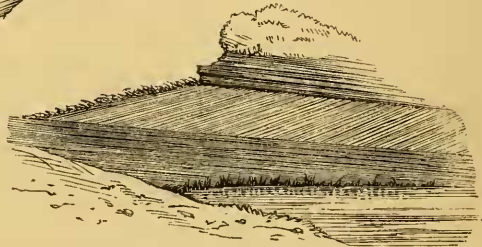
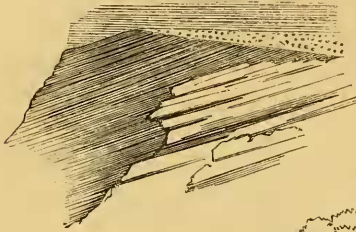
* This map, in so far as concerns the division between the fifth-stage Crag and the beach stages, must be taken as a very imperfect approximation, the chief part of the Crag area being hidden under the great heaths formed of the lower-Drift beds; the object is to show the features presented by the two Crags in their mode of deposit. The district on the east of the Deben, between Woodbridge and Ramsholt, may be taken as a tolerable approximation to exactness.

into two structural parts. These parts are respectively Crag possessing none of the characters of a deposit formed under water, and Crag with the usual characters of a water-deposit. There are to be observed in one pit at Hollesley (see woodcut *infra*) four

Pit near Hollesley.

North end of pit, looking N.W., fourth and fifth stages.

[This section is in its true vertical position relatively to the section below.]



South end of pit, looking N.E. Three Beach stages.

distinct stages of the first-mentioned Crag, one over the other, covered partially by the Crag with the character of a water-deposit; and in consequence of that quintuple exposure, I shall, for convenience, distinguish the one division as the beach stages of Crag, and the other as the fifth or horizontal Crag.

Of these beach Crag the three inferior stages are not altogether constant in their direction, although, where exposed, they have for the most part a distinguishable uniformity of direction in the inclination of their planes of stratification. There is only one other section (that at Brockstead in Sutton) where so many successive beach-stages are exposed. The less frequent exposure of the more inferior stages, or at least of the two lowest, and the extent to which they have suffered from the denudation consequent upon the formation of each succeeding stage, render it difficult satisfactorily to divide any of them, except the uppermost, into stages capable of identification with each other at every exposure. This, however, is not the case with the fourth or uppermost of the beach stages. From the great thickness often exhibited by this stage, and from the more partial denudation by a succeeding stage to which it has been subjected, this fourth-stage Crag presents the means of accurate identification.

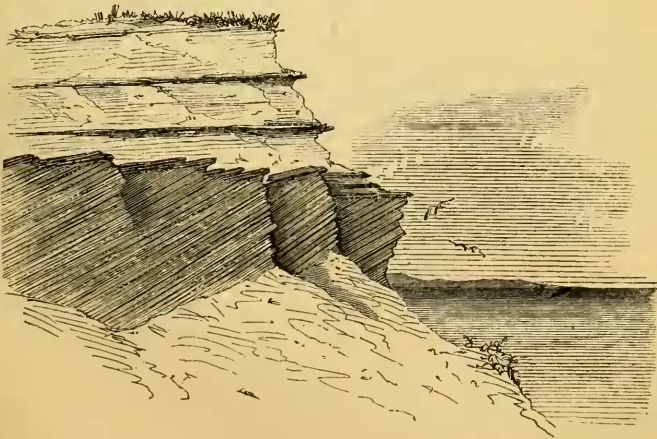
The angle made with the horizon by the planes of stratification of the fourth stage presents everywhere south of Hollesley a remarkable uniformity, varying between 25° and 35° ; and this Crag also possesses a direction of inclination in its planes most unvariable, being from N.N.E. to S.S.W.; its surface, where not covered by the fifth stage, is generally deeply eroded; and its thickness in some places, as at Newbourn, is not less than 20 feet. North of Hollesley, beach stages are exposed in several sections in Butley and Sudbourn parishes, but, from the absence of that uniformity of direction possessed by them in the more southerly exposures, they do not present the same means of identification.

No one who has, as I have done, measured the angles made by the laminae with the horizon, in the sections presented by the beach Crag, could suppose these Crag to have been deposited under water; the constancy of direction and the parallelism of their planes precludes any idea of false bedding, so called—a feature common enough in the horizontal or fifth-stage Crag and in some parts of the overlying sands. In some places, as at Trimley, these beach Crag contain no shells for a space, and then the shelly laminae recur; but both have their laminae inclined alike in all respects.

The subjoined actual copies of some of the more characteristic sections of beach Crag, at places selected for their great distance from each other, will afford an idea of their characters.

Bluff in Bawdsey Cliff.

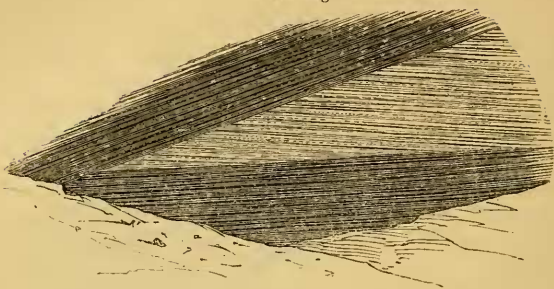
Fourth stage. Crag overlain by lower Drift.



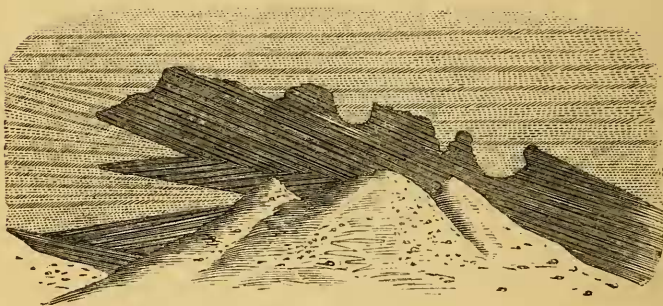
N.B. The inclination of the laminae is here represented greater than it should be; the inclination is about 35° .

Pit at Crag Hall, Tattingstone.

Three Beach stages.



Beach Crag overlain by lower Drift, in Pit near Melton Church.



In one place only (with the exception of a bed peculiar to Walton Naze, and presently referred to) could I find any indication of a water-deposit. This section is at Butley, near the Abbey: a bed is there exposed, underlying a true beach stage, more sandy, and stratified in a peculiar elliptical manner, resembling the grain of wood where knots have been cut through; and it appears to me to afford indications of having been produced in a very shallow eddy. Nothing also is clearer than that this inclined stratification, which at first sight resembles horizontal strata tilted by upheaval, is due to no elevating action, as, independently of the great area over which the fourth stage extends being inconsistent (on such an hypothesis) with its limited thickness, the inferior stages on which it rests often exhibit a less inclination than does the overlying fourth stage.

At Walton Naze, however, underlying the fifth stage and two subjacent beach stages, a bed of Red Crag occurs, lying on the London Clay, which differs entirely from any other Red Crag known. It is destitute of stratification, and is of a greyish-brown colour. It alone, of all the Red-Crag beds, yields shells in the condition in which they died—bivalves not unfrequently

with both valves united, and univalves with the pullus unimpaird. This bed, lying at the southernmost extremity of the deposit, presents the only instance of Red Crag, other than that of the fifth stage, which has been deposited under water; and it is destitute of those derivative Coralline-Crag shells that so largely contribute to make up the mass of the rest of the Red Crag. The rest of the Red Crag, occupying as it does a hollow between the Coralline Crag on the one side and the London-Clay shore on the other, is largely composed of the degraded material of the Coralline Crag, as well as having been in each successive stage largely made up of the degraded material from the preceding stages.

The fifth stage, or horizontal and water-deposited Crag, does not uniformly cover the underlying beach stages; these, deeply furrowed on their surface, are very frequently covered only by the red sands of the lower Drift; while the manner in which the fifth stage spreads up to and over the beach stages (almost always the fourth) shows that it has been formed in channels cut through the pre-existing beach, and afterwards silted up. It is under this fifth-stage Crag alone that the workings of phosphatic nodules, so far as I have seen them, occur*. I learn from Mr. Colchester that this material has been obtained from beneath the Coralline Crag; but not only have all the nodule-workings in the Red Crag that I have visited been under this stage, but wherever the beach stages are to be found resting on the Clay, as at Bawdsey and Walton, the nodule-band does not occur. This band, often of nearly a foot in thickness where worked, and largely intermingled with rolled *Pectunculi*, thins off gradually as the fifth-stage Crag leaves the Clay and rises over the beach stages. I have traced it so rising in numerous instances. At the watercourse near Methersgate Dock, Sutton, it appears overlying beach stages, whence, going eastwards, the extensive (but now discontinued) nodule-workings immediately over the London Clay occur; and on quitting them, the band rises again, on the eastern side, over beach stages. At Bawdsey the band first occurs high up in the cliff, covering beach stages, and descends to the southwards towards the river, nearer to which, and inland, extensive workings have taken place. At Tattingstone it occurs at the top of the section, underlying fifth-stage and covering beach Crags, while at the junction there of the beach Crag with the Coralline Crag it is

* At the base of the beach Crags small nodules may be found, forming a thin band interspersed with Crag; but they are intermixed with pebbles in such proportion that the pebbles are to the nodules as nearly 10 to 1. There is no similarity whatever between these minute bands and the true *Pectunculus*-vein of nodules.

absent. The portions of this band rich enough to work are those resting on the clay, being the deeper parts of the channels thus eroded through the older beach, the band becoming poorer as it rises up the sloping sides formed of beach Crag. Many of the sections of this fifth stage expose a thickness of not less than 20 feet of it; and one near Sutton Hall (now open) is a furlong and a half in length, and full of the most intricate false bedding. An interesting illustration of one of these channels is afforded by the pits at Foxhall and Bucklesham. (See Section A.) The *Pectunculus*-band with nodules invariably underlies the fifth stage only where that stage rests on the clay; when the stage rises over the beach Crag, the nodule-band either becomes feeble or disappears altogether. The Crag of the fifth stage may always be detected at a glance, and distinguished from the lower stages by its horizontal stratification and the contrast it presents to the underlying beach stages. The Crag of the fifth stage, however, does not resemble the genuine deposit underlying the beach stages at Walton Naze by containing shells in the state in which they died; on the contrary, although manifestly water-deposited, the organic remains in it are as worn and travelled in appearance as those in the beach stages, and show their origin to have been mainly from the material of the older beach stages through which the channels have been eroded. While this seems to have been the mode of formation of the fifth-stage Crag, that of the beach stages seems to have resulted from a sea forcing itself backwards from the shore by the growth of the beach that it heaped up, until, by a slight subsidence, the sea, recovering its place, planed down the old beach into the small thickness that we find the lowermost stages now presenting, and recommenced the process of beaching up and forcing itself back.

The fifth stage, south and west of Chillesford, is everywhere divided from the overlying red sands by a line of erosion, sometimes very faint, but generally strongly marked, and often, like the surface of the fourth stage where overlain only by the lower-Drift sands, irregular and deeply cut in. At Chillesford, however, the fifth stage (under which I could not detect the nodule-band) resting upon a beach stage, passes up, without the slightest break or line of erosion, into the micaceous sands and laminated clays first noticed by Mr. Prestwich in 1849, and which have as their characteristic fossil the *Mya truncata* in the position in which it lived; and these sands and clays, again, pass up in other places (as at Iken and Aldbro'), without a break, into the extensively developed sands of the lower Drift. At Chillesford (and it is here alone that I have been able distinctly to recognize it) we have the unbroken passage upwards of the fifth-stage Red Crag

into beds that unquestionably underlie, and pass gradually into, the great deposit of sands and gravels which cover the whole of Suffolk and are extensively developed in Norfolk and Essex, and which themselves pass upwards, without the least break, into the more widely spread northern Clay drift.

The geological conditions under which the peculiar formation of beach Crags was accumulated demands a special consideration, from the circumstance that it seems to afford a solution of the question of the relationship between the Red and the Fluvio-marine Crag. The latter, occurring at intervals from Norwich to Thorpe, near Aldbro', ceases almost at the place where the Red Crag first appears. The absence of any superposition in the two formations has hitherto left their relative ages in doubt; and since fluvio-marine conditions obtain in the one, and purely marine conditions in the other, inferences that might otherwise be drawn from a comparison of their fauna are consequently of less value.

The unvarying N.N.E. to S.S.W. direction presented everywhere south of Hollesley, and from Melton and Bealings on the west to Bawdsey Cliff on the east, is precisely that possessed by the trend of the Coralline Crag, uncovered by any Red beach Crag, from the point where it first comes to the surface north of Aldbro' to its termination at Gedgrave. This also is the direction which was detected by Sir Charles Lyell in the cliff of Coralline Crag buried in Red Crag at Sutton. According to the view I take, it is, in reconstructing the bay of the Red Crag, only necessary to assume the prolongation of that ridge or barrier of Coralline Crag in the same direction from Gedgrave southwards, over what is now covered by the sea. (See the continuation-line suggested on the map.) The production of this ridge, composed as it is of the Bryozoon-bank of hard rock, capable of resisting the waves, would give rise to a long tongue-shaped bay running up between it and the shore-margin of soft London Clay, in which these successive accumulations and destructions of beach-deposit might readily take place during slight intervals of subsidence. The direction of beaching up, then, would be determined by the particular contour of the bay and the direction from which the sea had access to it. The evidence available to show that the beach Crags never covered the greater part of what now remains of this barrier, although necessarily only negative, is of the strongest character that such evidence can afford. Firstly, it is along this line, and *there only*, that the Coralline Crag occurs uncovered by the Red; secondly, the Coralline Crag consists of three parts,—the lower of sandy beds, rich in Mollusca, preserved nearly as they lived; the middle of the rocky Bryozoon-bank; and the upper of a thin bed, some

3 or 4 feet thick, formed apparently of the disintegrated material of the Bryozoon-bank, and destitute of perfect fossils; this upper bed exhibits indications of having, during the period of its formation, been beached up, somewhat similar to those afforded by the lower stages of the Red Crag, suggesting comparisons with the beach of decomposed coral fringing existing coral shores. Now over this line, this thin and easily denuded upper part remains intact, with the Chillesford beds in places resting upon it; and it is almost inconceivable that so tranquil a sea as that depositing the Chillesford beds could have so evenly removed every trace of Red Crag, and spared this perishable upper portion of the Coralline Crag. It is also worthy of note that over this area the lower beds of the Drift sands exhibit peculiar oblique stratification not observable elsewhere, as though this ridge were continued as a shoal in the Drift-sea and produced a quasi-beaching of the sand over it at low water.

These arguments might be pursued further; but those given, I venture to think, justify me in the view I take that this ridge shut in the Red-Crag bay during the whole of the deposit of the beach Crag. The Chillesford Sands and Clays sweep round the Coralline-Crag ridge, but do not cover every part of it: their absence may be due to denudation taking place at the time when the existing valley-system was formed; but I am inclined to think that these beds even, although extensively overlapping those of the Red Crag, as well of the fifth as of the beach stages, did not quite cover the Coralline-Crag ridge; and, although I have not ventured so to represent them in the section, they may possibly be found, in some places, absent between the Drift sands and the Coralline Crag.

I should have felt much hesitation in thus offering a section so different from that given by Mr. Prestwich, in 1849*, as the result of the investigation by himself, Mr. Austen, Mr. Morris, and Mr. Tylor, but that I learn from Mr. Prestwich that he no longer adheres to the section so given. That section represented the Chillesford beds as resting unconformably on both the Red and Coralline Crag, whereas it appears to me evident that these Chillesford beds are but the continuation of the fifth or water-deposited stage of the Red Crag.

These Chillesford beds do not occur in the southern part of the Red-Crag area; the Drift sands there rest invariably on the Red Crag of either the fifth or a beach stage. The line of erosion everywhere dividing the fifth as well as the beach stages of Crag from the overlying sands, shows that these channels, after they had silted up, had become dry land; and keeping in view, therefore, the very limited thickness of these laminated

* Quart. Journ. Geol. Soc. vol. v. p. 345.

clay-beds, it is not improbable that they were formed in the small interval between the close of the fifth-stage Crag and the commencement of the deposit of the Drift sands, their sediment being furnished by the discharge of the streams to the northward, which, during the time when the Red Crag was accumulating, deposited the Fluvio-marine Crag, but which streams, at this subsequent period, under the effect of the recession at this point of the coast-line, had ceased to produce fluvio-marine conditions over this portion of the area. The base of the Drift sands, where it rests on the Red Crag, is often much mixed with loam, producing the flaky dark-red beds that immediately rest upon the eroded Crag, and furnishing, where the denudation has reached down to them, very rich lands. It appears, therefore, to me that in these we may have the equivalents of at least the laminated clays forming the upper portion of the Chillesford beds.

Crossing the ridge of Coralline Crag never covered by Red, we reach, at Thorpe, two miles north of Aldbro', the true Fluvio-marine or Norwich Crag. So far as I could learn, this solitary pit at Thorpe constitutes the only exposure of Fluvio-marine Crag south of Southwold Cliffs, a distance of eight miles further north. This exposure seems to be due to a fault bringing up the Fluvio-marine beds at this point through the overlying Drift sands which form the surrounding country*. The pit is now nearly overgrown with grass; but the beds appear to have been brought to the surface and denuded at the period of the formation of the valley-system; so that there are no means afforded of testing their position relatively to the Chillesford beds. The upper part of these Chillesford beds, composed of the laminated grey clays, occurs at a brick-field between Thorpe and Aldbro',—at which place they are pierced in the well down to a Crag which the workmen described as the yellow Coralline Crag of the pit just below, about a furlong distant, and nearer Aldbro'. The latter pit occurs at a lower level than the brick-field, and is composed of Coralline Crag; but the valley-denudation has swept the top of the pit clear of all the overlying Drift sands and of everything that may have occupied the interval between it and these sands, with the exception of two or three very minute traces of a Crag that resembles the Red, but which is so comminuted as to be incapable of identification;

* There is evidence of considerable displacement between Thorpe flag-staff and Sizewell Gap; and at the latter place the displacement has been great enough to bring down the upper Drift, that is otherwise quite denuded over this area, by a sharp pitch into the midst of the lower-Drift sands. (See Section B.) A pit there shows it inclined at a considerable angle, resting on the lower Drift.

with those traces, however, is preserved more perfectly a band of phosphatic nodules that I felt no hesitation in identifying with the basement band of the fifth-stage Red Crag. I entertain no doubt that this trace of Crag does not belong to any of the beach stages; and the only question that presents itself to me is whether it may be a remnant of the base of the Fluvio-marine Crag: that Crag, being water-deposited, may, like the Coralline, have in places under it these nodules. The means of ascertaining to which of these two this trace of Crag belongs could only be afforded by an excavation in the Aldbro' brick-field. In colour the Thorpe beds do not at all resemble this trace of Crag, which is ferruginous; and the impression I entertain is strong that the two are distinct. There can be little doubt that this Crag with the nodule-band underlies the clays forming the brick-field higher up the rise; and in that respect their relative positions agree with those we find on the opposite side of the Coralline-Crag ridge, where fifth-stage Crag passes at Chillesford up into these beds without interruption.

The conclusion that I have formed from these observations is that the Fluvio-marine Crag of Thorpe is inferior to the fifth-stage Red Crag, and as old therefore, at least, as the uppermost beach stage. It must be admitted that the evidence for such a conclusion is very incomplete and unsatisfactory; but the general consideration of the geographical conditions of the period furnish, to my mind, a support to the inference I have drawn. There can be little doubt that the fifth-stage Crag was introduced by a slight depression. That depression would enable it to cover, although very thinly and feebly, portions of the Coralline Crag never covered by the beach stages. Since this faint trace of Crag at Aldbro' immediately underlies the laminated clays, it must (if not the Fluvio-marine itself) be newer than the Fluvio-marine Crag; or else the latter is newer than the laminated clays, in which case we ought to find it overlying the clays; but such is not the case—the clays passing, without a break, up into the sands of the Drift. If, on the other hand, it be identical with the trace of Crag at Aldbro' underlying the clays, it must be at least as old as the fifth-stage Crag, that underlies and passes up into those clays. I can therefore come to no other conclusion than that the Fluvio-marine Crag is as old as the Red Crag, and most probably older than that part of it represented by the fifth-stage or water-deposited Crag.

The descriptions with which we have been furnished by Messrs. Woodward and Gunn, and by Sir Charles Lyell, of the beds occurring along the coast northwards from Southwold, have not been of such nature as to afford any satisfactory comparison with the formations I have been discussing. Nothing less than

a close survey of the area would afford the means of testing how far their horizons accord; the grouping, however, of the Drift sands and gravels which, as I have to show in the case of Suffolk and Essex, succeeded the Red Crag, goes to prove that there was a gradual and continuous recession of the coast-line during the period succeeding the Red Crag; so that, by the incoming of the great northern Clay Drift, that coast had reached the western side of those counties. This and other circumstances not within the compass of this paper lead me to a belief that some of the deposits of the north-east of Norfolk belong to an horizon at least as old as the lowest beach stage of the Red Crag. The view that I take of the direction of the coast-line prevailing during the Red-Crag period is indicated by the easternmost dotted line on the small map annexed to this paper.

The formation into which the Chillesford beds pass, and which overlies in common those beds, the fifth stage, and the beach stages of Red Crag, is one occupying a large area; and in that respect, and in the thickness of its beds, it occupies a far more important position than do any of the beds I have been discussing. From its distinct character, both in the material composing it and in the limited and definitely marked spread of the deposit, as well as in the entirely different geographical conditions under which it was formed, it appears desirable to distinguish this deposit from the great overlying Clay drift which has already received the designation of the Boulder or Northern Clay Drift. I propose therefore to call it the Lower Drift of the Eastern Counties. This formation is composed, over the Red-Crag district, almost exclusively of sands which at the bottom are loamy and rich and highly ferruginous, but gradually become more siliceous in their upper parts. Although where the valleys cut through the deposit down to its lower beds and the Red Crag rich lands occur, yet the upper or siliceous beds exposed as tablelands over large tracts form the barren heaths or sheep-walks of Eastern Suffolk. These beds distinctly pass under the Boulder-clay wherever the denudation has not removed the latter: every river-valley of East Suffolk and North-east Essex affords the means of testing this, as the whole of the more seaward extremities of these valleys have been cut through this formation, leaving the upper or Clay Drift as cappings on the higher grounds, the mixed soils of these counties being formed by the overlying clays where denuded down to a crust thin enough to mix with the underlying sands. These sands gradually change to gravels as the formation extends southwards, while they, after passing under the Clay or upper Drift, reappear on the western sides of Suffolk and Norfolk, forming the very extensive sand-tracts around Brandon. There

they repose on the Chalk, while in the south-eastern area they repose, in the condition of gravels, on the London Clay. The southern boundary of this formation may be indicated in some parts with such precision that it can with certainty be averred that this was the shore in this direction of the bay of the period. Along the coast south of the Stour, the denudation has in many places removed this formation, leaving the London Clay to form the coast-line—the lower Drift appearing a few miles inland, and furnishing outliers occasionally nearer the coast. Ranging south as far as Chelmsford, its southern edge may be traced crossing the railway-cutting a few furlongs south of Chelmsford Station, from which place it extends eastward to Danbury Hill, where it forms an outlier, apparently nearly 100 feet in thickness, resting on London Clay. Between those two points it occurs at the villages of Badow and Sandon. West of Chelmsford, it passes by Writtle, and, a mile north-west of that place, is lost under the Boulder-clay, a deep section being exposed at that place about a furlong only from its disappearance under the overlying Clay Drift. From that point to Badow, the margin of the bay depositing the beds may be indicated with certainty; but east of Badow its boundary-line has been destroyed by the great denudation that has removed the Bagshot gravels and the upper beds of the London Clay. The precise margin alluded to is shown in this way. At intervals over Southern Essex, the Bagshot sands and gravels, that originally extended, for a thickness of about 50 feet, continuously over the London Clay, now remain as outliers on the summits of the higher hills, as at Raleigh, Galleywood, Langdon, Stock, Margaretting, Warley, Shenfield, South Weald, Epping Forest, &c., uncovered by any Drift-beds, the upper or Clay Drift having been removed from them, while the tablelands that range from Brentwood towards Epping on the one hand, and towards Ongar and the Rothings on the other, are capped by these Bagshot beds, covered with patches of the upper or Clay Drift, without the faintest trace of anything resembling the lower-Drift deposit between them.

These Bagshot beds possess so uniform a character, both in their constituent material and thickness, and are so evenly and uniformly covered by the Drift clay in immediate contact with them, where that remains undenuded, that the idea of any extension of the lower Drift over this area, during the interval between the two formations, is precluded. In addition to this, the lower Drift, wherever it occurs, has invariably eroded the whole of the Bagshot beds, so that it rests on the London Clay only. This process is conspicuous near Chelmsford: there the Drift gravels may be seen resting on the London Clay, while, within the distance of a mile, the complete beds of the Bagshot

series* cap Galleywood Common, the valley of the Chelmer having been cut through the line of contact. The same feature may be perceived all along this line between Badow and Writtle; and in Section C (Pl. XVII.), I have shown the original position of the beds of the lower Drift at their southern extremity, and the mode in which the valleys have been cut through the district. Considerable alterations of the relative levels have taken place here, as over all the rest of East Anglia, by the formation of the valley-system, so that the Danbury outlier is forced up far above the corresponding level of the old shore of the bay which may be represented by Galleywood, now much below the level of the lower Drift of Danbury. The section, however, is drawn without reference to any of these changes of level, in order that the position originally occupied by the lower-Drift beds may be better shown.

It is thus very obvious how the bay depositing this lower Drift advanced inland by erosion as much as or more than by depression. Several examples of this advance by erosion occur. A very interesting one is afforded by the section on the summit of the Chalk inlier forced up at Claydon in Suffolk (see the sketch below the map): this section marks a stage when the bay had advanced but a short distance inland from the Red-Crag bay. Another example is afforded by the well-sinking at Hasketon, near Woodbridge. The base of the London Clay is brought up at Kyson, and the clay at that place has a thickness of only some 50 feet between its base and the overlying Crag; but at Hasketon a well-sinking for 120 feet failed to pierce the London Clay, and was abandoned, while at a short distance on one side of this sinking, at a few feet higher level, the lower Drift was pierced for 60 feet; and on the other side of the London-Clay boring, both upper and lower Drift have been pierced for the usual thickness of the district. Moreover, on a third side, the upper or Clay Drift rests on this London Clay, and the valley has been cut through both

* In the Sections attached to the paper of Mr. Prestwich on the correlation of the English and Belgian lower tertiaries (Quart. Journ. Geol. Soc. vol. xi. p. 241), the middle and part of the lower Bagshot are represented as denuded from Langdon Hill. Whether the Essex beds represent the middle as well as the lower Bagshot, or the lower only, they at any rate are nearly complete on Langdon Hill. The Essex Bagshot consists of about 30 feet of sand and 20 feet of pebble-beds overlying the sand, and on these pebble-beds the boulder-clay, where not denuded, rests. It is the nearly complete preservation of these uppermost pebble-beds, on the various outliers where the Drift clay has been denuded, that shows that the lower Drift never extended over them; the Bagshot pebble-beds may be traced complete along the outliers until they pass under the Drift clay. Nothing of the Bagshot series, beyond this sand and overlying pebble-bed, was ever deposited in Essex.

clays. These variations occur within a radius of about a quarter of a mile from the London-Clay boring, showing that during the progress of the lower Drift the sea had eroded and encompassed an island of London Clay, by the sides of which it deposited its sands, but the top of which was never covered by that sea, but was overflowed when the great depression brought in the upper Drift. The lower Drift is cut through by the railway from London to Yarmouth, without any break, from the point where it is lost under the upper Drift near the Norfolk boundary of Suffolk to its termination at Chelmsford; and the railway-cuttings afford a continuous section, and show the sands that occupy the Crag-area and the country to the northward gradually changing into gravels as the more southern portions of the deposit are cut through.

I have indicated on the small map the outcrop of this formation from beneath the overlying Clay Drift along the eastern side of it; but the western outcrop I have not ventured to delineate, as it is some years since I visited the extensive development of the deposit around Brandon. The junction-line connecting the western side of that development of the deposit with the emergence of the deposit from beneath the Clay at Writtle (and forming between those places the western boundary of the formation), being hidden by the overlying Clay Drift, is only to be ascertained accurately by the well-borings: these I have not yet been able to collect, but I have indicated on the map what may be taken as an approximation to that line. North and west of Brandon, the lower Drift has undergone a denudation along the fen-border; and I have not had the means yet of testing precisely where the boundary-line of the deposit, shown by the upper Drift resting on the Secondaries, as in Lincolnshire and Bedfordshire, without the occurrence between them of any lower Drift, is to be drawn.

The thickness of the lower-Drift beds appears very uniform: the well-sinkings above Woodbridge give from 60 to 70 feet. Nearly the entire deposit is exposed at the scarp by Wilford Bridge over the Deben, near Woodbridge, the Crag occurring about 5 feet below the pit, and the upper or coarse gravel-beds remaining undenuded; the thickness there is between 60 and 70 feet. Danbury seems to show a greater thickness, but there perhaps something may be deducted on account of a slight bending of the beds over the hill.

The transition from the lower to the upper or Clay Drift, although most abrupt, is unmarked by the slightest evidence of violence; the sands and gravels give place to the clay sharply, passing, by a very thin band of loam, into each other. Sections showing the passage are not so common as might, from the

structure of the county, be expected; good sections, however, showing the passage may be found in the pit behind Sizewell Gap already alluded to, in a pit a mile west of Leiston, on the Saxmundham road, and in a pit at Hoo, a mile on the Charsfield side of the bridge over the Deben. Over Suffolk, the upper part of the lower Drift is marked by beds of coarse gravel, the stones being large and angular, and sparsely scattered in the sand: they are unlike the gravels that occasionally, even in this area, occur near the base of the deposit, the latter being more rounded and thicker-bedded, while the former have the character of being ice-borne, and much resemble the small boulders occurring in the Drift clay. The characteristic pebble of the lower-Drift beds is a pink quartzite, which I have identified more nearly with a quartzite from Freyburg than with any other. It is probable that the lower-Drift bay, of which only the lower and western border touched England, extended across the north of Europe to a great distance in the direction of Germany, and that the gravels accumulated in it were largely supplied with detritus carried from that country along the southern shore of the bay. The depression that introduced the upper Drift seems to have been both sudden and uniform; and if the view be well founded which I have taken as to the formation of the valley-system* of Eastern England—that all the inequalities of surface now existing there are of an origin later than the Drift—we may conceive that a sudden, though moderate, depression would at that time have submerged the very extensive area occupied by the Jurassic, Cretaceous, and Tertiary strata: the materials of these, and particularly the two former, it is well known, have largely contributed to the upper Drift, the supply of which appears to have been chiefly furnished from the British strata. The thickness of this upper Drift over Suffolk and Essex does not, where least denuded, exceed the maximum thickness of the lower Drift; and its deposition seems to have ceased before the spreading of the great erratics of the northern counties commenced. At any rate, the great erratics are generally absent over the southern part of the eastern counties; and as no denudation could well have removed them, but must have allowed them to sink upon the uncovered beds, we may assume that the causes giving rise to the erratic distribution of northern England did not exist over these more southern counties. Probably before the high lands of the northern part of England were submerged, the great plain then formed by the strata newer than the Trias had sunk to a depth beneath the sea too great to arrest icebergs on their transit, if these were the means of spreading the erratics; on the other hand, the greater distance of these counties from

* *Phil. Mag.* ser. 4. vol. xxvii. p. 180.

the high lands of the north of England would exempt them from any part that glaciers may have played in the distribution of the great boulders of that part of England.

Notwithstanding the confusion that has existed as to the relationship to the Drift borne by the freshwater formations of Grays, Ilford, Clacton, Stutton, Copford, Lexden, Hoxne, &c., I take it to be now well understood that these and similar formations in other counties are altogether posterior to the Drift period, having been deposited in the valleys that resulted from the upheaval of the bed of the upper-Drift sea, and from the denudation that accompanied such upheaval. Being limited for space, I have not referred to these beds, but confined myself to marking into the map of the Red Crag district the only deposit of this nature (that of Stutton and Wrabness) occurring within it. It will be seen that the Stutton and Wrabness beds rest on the London Clay, which previously to their deposition had been laid bare by the denudation of both Drifts, and which denudation accompanied those symmetrical movements that elevated the upper-Drift sea-bed, and gave rise to the inequalities of surface over the East of England which form the subject of my paper on the valley-system before alluded to. The other correlated freshwater deposits named above are identical with that of Stutton in their position relatively to the Drift, although they vary in the bed they rest upon, according as the denudation has in a greater or less degree eroded the valley previous to their deposit; but, within the limit of the period elapsed since the upheaval of the Drift sea-bed, these deposits may to a small extent vary in age among themselves. The greater contiguity of the Thames valley to the centres of upheaval producing the valley-system, but more particularly its greater contiguity to the great rectilinear upheavals of the Weald and South of England which succeeded the general upheaval producing the valley-system, has, as I conceive, caused in that valley greater changes of level among its deposits than is the case with the beds accumulated in the valleys of the rivers of northern Essex. The precise correlation in age of the valley-deposits of the respective areas is therefore, I think, to be satisfactorily arrived at rather by close palæontological analysis than by comparisons of level and physical structure.

APPENDIX.

Sections of Red Crag.

- ALDERTON.** On the Ramsholt road, three-quarters of a mile from Alderton.—Fifth stage, laminated with red sands, and false-bedded. No line of erosion visible. Traces of a beach stage at bottom. Nodule-band occurs.
- BAWDSEY.** Sea-cliff.—Fifth stage. Fourth and two other beach stages.

Nodule-band visible high up in the cliff. (See woodcut of fourth stage.)

BEALINGS (LITTLE). Pit in a shrubbery of the residence of — Colvin, Esq.—Fourth and fifth stages.

BENTLEY. Pit 100 yards from railway station.—Fifth stage. Nodule-band and two beach stages. Deep line of erosion between fifth stage and sand.

BUCKLESHAM. Pit south of Rectory.—Two feet of fifth stage, with strong line of erosion between it and the sand.

Pit north-east of Rectory.—Fourth and fifth stages; line of erosion between the latter and the sand.

Another pit in adjoining field, with the beds much shattered.

BUTLEY. Near the Oyster Inn.—Two stages visible.

Another pit near the mill.—Three stages visible.

Several large pits five furlongs south-west of church, containing three beach stages, the lowermost exhibiting traces of being not true beach, but formed in shallow water.

CHILLESFORD. Below the church.—Fifth stage and a beach stage.

FOXHALL. Pit near to and east of Foxhall Hall.—Fourth and fifth stages.

Nodule-working on hill 300 yards south of last pit.—All fifth-stage Crag resting on London Clay, and overlain by red sands.

Another working, a quarter of a mile south of last pit, and five furlongs north-west of Bucklesham.—Similar to last section.

HOLLESLEY. A farm-yard nine furlongs south-west of church, beside road to Shottisham.—Fifth stage and four beach stages. (See woodcut.)

Pit 300 yards east of the last.—Fifth stage; only faint line of erosion between it and the sand.

Pit 200 yards south-east of church.—Two beach stages.

Pit close to and immediately north of church.—Fourth stage composed of sands and gravels only, the planes dipping N.N.E. to S.S.W. No shells.

Pit a quarter of a mile north-north-west of church.—Similar to last pit.

Pit beside farm-house, three quarters of a mile north-north-west of church.—Fifth stage only, brought up through the sand by a fault.

IPSWICH. Side of road leading from Goldroods down to Belstead Bridge.—Fourth stage.

LEVINGTON. Half a mile east of church.—Fifth stage. Line of erosion visible.

Immediately south of church, on opposite side of road, a small section of fifth stage.

MELTON. Pit on by-road five furlongs south-west of church.—Fourth and lower beach stages. (See woodcut.)

NACTON. Nodule-working north side of road to Levington, and midway between each place.—Fifth stage, resting on London Clay.

NEWBOURN. A quarter of a mile north by east of Bucklesham mill.—Fourth stage, dipping N.N.E. to S.S.W. Composed of sand only.

A quarter of a mile north-east of church.—Fourth stage. A thickness of 20 feet of beach is here exposed.

RAMSHOLT. Bluffs by the Dock Inn.—A beach stage overlain by fifth stage: faint line of erosion between the latter and the sand. The beach-stage laminae here have an inclination of nearly 45°.

Pit a quarter of a mile west-north-west of church.—Beach stage overlain by fifth stage. Nodule-band between them.

A nodule-working 50 yards south of the last.—Fifth stage, resting on the Clay.

The cliff between Shottisham Creek and Church-farm.—The fifth stage is visible; but the beach stages are probably obscured by the talus. The Coralline Crag occurs here at the base of the cliff.

SUDBOURN. Pit half a mile north of the village, corner of Tunstall Heath.—Beach stage only.

Two pits are given by Mr. Prestwich (*Quart. Journ. Geol. Soc.* vol. v. p. 352) of Red Crag on Coralline, north-north-east of Sudbourn Church; but I could not find them. There is probably some clerical error in the directions.

SHOTTISHAM. Nodule-working a quarter of a mile north of Shottisham Hall.—Fifth stage resting on London Clay.

Another pit, nearer to Shottisham Hall.—Fifth-stage, Crag exposed.

SUTTON. Watercourse half a mile east of Metersgate Dock, on the Deben.—Three beach stages and fifth stage. Nodule-band between the latter and beach stage.

South-east of the last are extensive abandoned nodule-workings; and

Still further east, leaving the workings, fifth stage appears over beach stages, with nodule-band between them.

Nodule-working 150 yards west of Sutton Hall.—A very large section of fifth stage resting on London Clay.

Pit opposite the Meeting-house at Brockstead.—Four beach stages are visible, overlain at one corner only by fifth stage.

Pit half a mile south of Pettistree Hall.—Fifth stage much washed up on the surface. Two Coralline-Crag pits occur to the north-east of it.

TRIMLEY. Four pits occur here, from half to three-quarters of a mile north-east of the churches. Two of them have fourth stage overlain by fifth-stage Crag. Another contains fourth stage only (no shells); and the other contains fourth stage and an underlying beach-stage.

TATTINGSTONE. Pit five furlongs north-north-west of church.—Fifth stage, with nodule-band overlying two beach stages.

Pit close to Tattingstone Hall farm.—Fifth stage underlain by nodule-band and two beach stages. The Coralline Crag occurs here; but the beds have been broken and shifted by faults.

Pit behind Crag Hall.—Three beach stages. (See woodcut, page 188.)

WALTON NAZE. Sea-cliff.—A brown Crag, full of water, rests on the Clay containing shells preserved as they died, overlain by two beach stages and by fifth stage.

The Coralline-Crag pits not mentioned above are all at Sudbourn, Iken, Orford, and Aldbro'. They are mostly enumerated by Mr. Prestwich in *Quart. Journ. Geol. Soc.* vol. v. p. 352.

The sections of Chillesford beds are also given by him in the same list; but, in addition to them, the following sections of these beds may be found by reference to the Ordnance Map:—

Pit 200 yards north of road from Chillesford to Sudbourn, three quarters of a mile east of the brick-field.

Pit by Iken Church.

Ditto half a mile south-west of Calton farm.

Brick-kiln one mile north-north-west of Aldbro'.

N.B. Coralline Crag has also been found in digging at Trimley (authority of the late Mr. Acton).

XXI.—*On the Occurrence of Amæbiform Protoplasm, and the Emission of Pseudopodia, among the Hydroida.* By Professor ALLMAN, F.R.S.

[Plate XIV.]

ONE of the most striking peculiarities of the hydroids which compose the family of the *Plumulariadae* is the occurrence among all of them of certain singular bodies which are produced as buds at definite spots upon the hydrosoma. These bodies have been examined by Huxley* and also by Busk, who, from the fact of their often containing clusters of large thread-cells, has named them "nematophores" †.

The most important character, however, of the nematophores has hitherto escaped notice; and yet it is one full of interest, involving as it does the manifestation of phenomena whose existence among the *Hydroida* has not as yet been suspected.

The species which I have had an opportunity of most thoroughly examining are *Aglaophænia pluma* (*Plumularia cristata* of most authors) and *Antennularia antennina*; and I shall confine the present paper to a description of the nematophores and their contents in these two hydroids.

1. *Aglaophænia pluma*.

In *Aglaophænia pluma* there are two sets of nematophores—a mesial and a lateral (Pl. XIV. figs. 1–4). The mesial nematophores (*a a*) are situated exactly in the mesial line, one being placed in front of every hydrotheca. These mesial nematophores consist each of a chitinous tube with peculiar contents. The tube springs from the base of the hydrotheca, and, thence continuing for the greater part of its length adnate to the front of the hydrotheca, terminates in a free tubular spine-like process a little below the orifice of the latter. It opens below into the common tube of the chitinous periderm; and just before its termination its cavity communicates by a lateral orifice with that of the hydrotheca, while its free end opens externally by a very oblique aperture.

* Huxley, "On the Anatomy and Affinities of the Medusæ," Phil. Trans. 1849, p. 427.

† Busk, Hunterian Lectures (MS.), delivered at the Royal College of Surgeons, London, 1857.